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# RELATION OF TIMBER GROWTH AND MORTALITY DUE TO INSECTS IN THE MODOC NATIONAL FOREST

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Course 202B
Division of Forestry
University of California

April, 1933

U. S. GOVERNMENT PRINTING OFFICE: 1928 J 76133

# RELATION OF TIMBER GROWTH AND MORTALITY DUE TO INSECTS IN THE MODOC NATIONAL FOREST

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Course 2023
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University of California

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RELATION OF TIMBER GROWTH AND MORTALITY
DUE TO INSECTS IN THE MODOC NATIONAL FOREST

## I. Objectives of the Studies of the Bureau of Entomology

During the last twelve years the Bureau of Entomology, U.S. Department of Agriculture, has kept a record of mortality losses of ponderosa pine due to insect infestations on a series of permanent plots located at various points in the forests of the Sierra Nevada Mountains. In 1931 a 10% cruise of these sample plots was made and increment borings were taken of all trees measured. In years previous to 1931, only the number of trees killed by insects was recorded.

The Bureau of Entomology has three objectives in this project:

1. To obtain information annually concerning the intensity and trends of infestations of forest insects (particularly bark beetles) in the forested areas of Region 5;

2. To attempt to correlate the intensity and trends of forest insect infestations with the physical factors of climate, soil, altitude and topography and the biotic factors of character of forest cover; methods of cutting and slash disposal and other human activities; predators; and parasites, as a basis for assigning causes for the fluctuating intensity of infestations;

3. To obtain information concerning the effects of heavy infestations on a stand, particularly as regards changes in the susceptibility of the stand to the infestation, and the character of the stand and reproduction or other vegetative growth.

This paper deals with the field measurements and methods of office compilation which were employed in studying Plot No. 1 of the series of permanent plots referred to above.

## II. Field Work

### (a) Description of the stand and area

Plot No. 1 is located in the Modoc National Forest. The plot is 320 acres in area and forms the south half of Section 22, Township 43 North, Range 4 East, Mount Diablo Meridian. The topography of the plot is uniform, with a slight southwest slope. The soil is of volcanic origin and there are several lava outcrops on the plot. The only outstanding surface feature is an intermittent stream running through the area from northeast to southwest. The plot is classified as Site 3 and represents a ~~very~~ low quality of this site grade. The forest cover consists of a mature virgin forest composed of:

Ponderosa Pine - 96% by volume
Incense Cedar - - 3% "
Juniper- - - - - 1% "

The stand is open, with heavy reproduction occurring in patches. It is classed as fully stocked, although many places have no reproduction while some of the patches of young growth are overstocked.

(b) Field methods employed by the Bureau of Entomology

A. Plot Survey

1. Reconnaissance survey. Plots were tentatively selected by means of a reconnaissance survey for the purpose of securing areas which would

a. be representative of general conditions within the region;

b. be representative of contrasting conditions. The plots were selected in pairs or series differing in as many respects as possible, yet typical of certain general conditions;

c. give an even distribution of plots throughout the region on the basis of timber types.

(No reconnaissance survey was made in the selection of Plot No. 1.)

B. Initial Surveys

1. Setting up plots. Plots were set up by a three-man crew which determined boundaries, located and marked cruise lines, mapped the plots and cruised a percentage of each plot.

2. Location of plot. Plots were located in respect to legal land divisions.

3. Marking plot. Boundary tags were placed at intervals of 5 chains on the long side of each plot and 5 chains on the short side. Cruising tags were placed every 2½ chains along cruise lines, so that the cruiser would be able to locate himself exactly with respect to the position of the plot.

4. Mapping plot. Maps prepared show topographical features, culture, drainage and timber types.

5. Description of plot. See Plot Data, Regional Survey, Form 6.

6. Stand cruise. A percentage cruise was made to determine stand composition, volume, increment, tree classes, growth, condition etc.

a. All trees were measured for d.b.h. with a Biltmore stick or a diameter tape. Trees were recorded in 2-inch diameter classes, the minimum size-group being the 12-inch class.

b. Trees were tallied by number of 16-foot logs, heights being estimated with frequent checks by a Forest Service hypsometer.

c. Increment cores were taken from all trees tallied. Borings were made at breast height on the north side of each tree. The cores were later measured in the office by means of a microscopic gauge, and yearly radial growth was recorded in hundredths of millimeters.

d. Trees were classified according to the system prepared by Mr. F.P. Keen of the Bureau of Entomology on the basis of Dunning's system of tree classification (Jour.Agr.Res.,V.36,pp.755-771,1928). The classes used were as follows:

Class 1 - Trees less than 75 years of age; blackjack type
Class 2 - Trees 75 to 150 years of age; immature to mature
Class 3 - Trees 150 to 300 years of age; mature

Class 4 - Trees 300 years of age or over; overmature

Subclass a - Crown length 75% or over; pointed top; thrifty, dominant
Subclass b - Crown less than 76%; thrifty; pointed or round top
Subclass c - Intermediate crown length and width; thrifty, flat crown
Subclass d - Crown length all types; unthrifty, suppressed

A comparison of Keen's tree classes with those of Dunning is as follows:

| Dunning Classification | Keen Classification |
|---|---|
| 1 | 1a, 2a |
| 2 | 1b, 1c, 2b, 2c |
| 3 | 3a |
| 4 | 3b, 3c |
| 5 | 4a, 4b, 4c |
| 6 | 1d, 2d |
| 7 | 3d, 4d |

The survey of Plot No. 1 was made in 1931, the mortality records having been taken in previous years.

C. Subsequent Plot Survey. The results obtained from the initial cruise are not to be projected into the future, but subsequent stand cruises will be made at intervals of five or ten years. These surveys will be made by a two-man crew instead of a three-man crew.

D. Surveys of Infestation. Annual cruises are to be made to determine the intensity of infestations. The purpose of these examinations is to determine the amount of loss due to the different species of insects.

Insect losses are determined by a 100 per cent ~~estimate~~ cruise of the plots. Infested trees are tagged. Cores are taken from each infested tree, and information regarding intensity and condition of attack and brood is recorded.

E. Photographic Records. Photographs are taken in each in order to record the infestations and their results.

F. Supplementary Cruises. Supplementary cruises are to be made in order to obtain records of losses over large areas. These cruises will be based on traverses, road strips, topographic cruises or other methods in order to give as accurate results as possible.

CORE ANALYSIS INSTRUMENT

The instrument used for the measurement of cores consisted of a binocular microscope mounted on a steel platform that formed the base of a worm gear slide. The motion of the slide was controlled by a hand-operated wheel which turned the worm, and at one end of the instrument there was a micrometer which measured the motion of the slide in hundredths of millimeters. This micrometer had a device by means of which the measurement of the motion of the slide was recorded only when wanted.

The slide consisted of two pieces of wood fastened together at each end. By a control wheel centrally located these two blocks of wood could be brought together or separated, and the core to be measured fastened in the space between them. This slide was mounted upon the gear.

In operating this instrument, the core to be measured was placed between the two blocks of wood, the control wheel tightened, and the top of the core shaved off with a razor. The slide was then placed on the rack. To make a reading the observer looked through the microscope, and by means of the control wheel moved the slide until the inner end of the bark coincided with the indicator in the microscope. The micrometer was then engaged and set at zero. By turning the wheel one year's growth could be measured, and after the

reading of the micrometer had been recorded the micrometer was again set to read zero, preparatory to measuring the thickness of the next annual ring.

III. Details of Records Obtained in Field

These records included the following:

1. A complete description of the stand. This was recorded on the "Plot Data - Regional Survey Form 6";

2. A map of the plot showing topographic features, topographic types, and roads and other improvements. See map entitled "Regional Survey of Plot No. 1" included in the appendix;

3. Cruise data of diameters and heights of trees, recorded on "Spotting Record Form 3";

4. Core analysis, made in the office after the field work had been terminated for the season. These data were recorded on the "Core Analysis Form";

5. Mortality records. A record of the number of trees lost, tallied by diameter classes for each year from 1925 to 1931. These records were summarized on a form which also contained a stand table for the same period. Mortality data were collected for the period 1921 to 1923, but no data were collected for 1924.

IV. Methods of Compilation of Data

This study is a portion of the third phase of the project of the Bureau of Entomology, namely:

"To obtain information concerning the effects of heavy infestations on a stand, particularly as regards changes in susceptibility of the stand to the infestation, and the character of the stand and reproduction or other vegetative growth."

(a) Objectives. The objectives of compilation were as follows:

1. To develop a method of determining the volume of timber growth for each year, so that the relation between growth and losses due to insects might be compared;

2. To compare the rate of growth with the mortality loss due to insects.

(b) Outline of procedure

1. Determination of volume

a. Compute average volume of each d.b.h. - o.b. class
b. Curve volume over d.b.h. - o.b.
c. Curve d.b.h. - i.b. over d.b.h. - o.b.
d. Curve volume over d.b.h. - i.b.

2. Determination of growth

a. Compute average diameter growth in millimeters for each diameter class (o.b.) and each year;

b. Compute diameter in millimeters of each diameter class for each year;

c. Construct individual curves for each d.b.h. class of volume over d.b.h. (i.b.) in millimeters; data taken from the curve of volume over d.b.h. (i.b.) indicated in Section 1.d above;

d. Read the average tree volume of each diameter class for each year;

e. Compute growth of each diameter class for each year.

3. Mortality

a. Determine the number of trees of each diameter class that have died each year. These data were obtained from the mortality record.

b. Determine volume loss in each diameter class for each year.

4. Increment

a. Determine the number of trees in each diameter class for each year;

b. Determine the volume of each diameter class for each year;

c. Determine the increment for each diameter class each year;

d. Determine the growth per cent of each diameter class for each year.

5. Net Increment

a. Determine net increment in volume for each diameter class each year;

b. Determine net increment per cent for each diameter class each year;

c. Summarize data on a diameter basis for the entire period;

d. Summarize data on a yearly basis, grouping all diameter classes.

(c) Details of Procedure

1. Determination of volume

a. Average volume of each d.b.h. class

The volumes of the individual trees were determined from "Volume Tables for Western Yellow Pine", prepared by the United States Forest Service in 1927, giving volumes in board feet by the

Scribner Decimal C rule, applicable to the entire range of the species. The field measurements of diameters and heights were then averaged by diameter classes in order to find the volume of the average tree of each class. In this step it was assumed that each tree was in the right diameter class, and that the average diameter of the trees of each class was equal to the midpoint of that class.

b. Curves of volume over d.b.h. (o.b.)

The volume of the average tree of each d.b.h. class was plotted over its diameter and a smooth curve drawn. In order to use this curve it had to be plotted on a large scale, of which Figure 1 is a greatly reduced copy.

c. Curve of d.b.h.(i.b.) over d.b.h.(o.b.)

Data concerning bark thickness were not obtained in this project, and use was made of a curve of bark thickness of ponderosa pine over d.b.h.(i.b.), which was very kindly provided by the California Forest Experiment Station (Figure 2). From this curve it was possible to construct a curve of d.b.h.(i.b.) over d.b.h.(o.b.)--Fig.3.

d. Curve of volume over d.b.h.(i.b.)

This curve was constructed on the same graph as the curve of volume over d.b.h. The diameter scale, instead of representing d.b.h. outside bark, then represented d.b.h. inside bark. The values for d.b.h.(i.b.) were read from the curve of d.b.h.(i.b.) over d.b.h.(o.b) and their volumes were plotted and curved. (Figure 1)

2. Determination of Growth

a. Average diameter growth

From the summary of analyses of the green cores the average radial growth was determined for each diameter class for each year. This average radial growth multiplied by two gave the average diameter growth.

b. Diameter of each diameter class in millimeters

The midpoint of each diameter class was expressed in millimeters. The amount of diameter growth of each year was subtracted from the diameter of the following year. In this step it was assumed that the average tree of each diameter class had a diameter equal to the midpoint of itsdiameter class.

c. Preparation of individual curves

In order to determine the amount of growth for each year it was necessary to have a volume curve plotted on a large scale. In order to keep the curves to a size that is easy to work with, it was advisable to consider the curve of volume over d.b.h.(i.b.) as made

up of a large series of straight lines, each line representing the change in volume between successive two-inch diameter classes. From this curve two volumes were read off and plotted on each of the curves for individual diameter classes:

(1) The volume of the d.b.h.(i.b.), corresponding to the diameter class in question;

(2) The volume and d.b.h.(i.b.) of some diameter .5 to 1.5 inches less than the diameter class in question.

A straight line was then drawn between these two points. In this graph the diameter scale was changed so that it read in millimeters instead of inches (see Appendix).

d. Average tree volume of each diameter class for each year. Volumes were read from the individual curves to find the volume of the average tree of each diameter class for each year.

e. Volume growth. The growth in volume of each diameter class was computed for each year by subtracting the volume of one year from the corresponding volume of the following year.

3. Mortality

a. Determination of number of trees. The loss in number of trees in each diameter class each year was determined from mortality records.

b. Determination of volume loss. This was found by multiplying the number of trees lost from each diameter class by the volume of the average tree of the corresponding diameter. Here it had to be assumed that the average diameter of the trees dying each year in each diameter class had been equal to the midpoint of that diameter class.

4. Increment

a. Number of trees in each diameter class. The total number of trees on the plot in each diameter class was calculated for each year by adding the number of trees that died during any given year to the number of trees present the following year.

b. Volume in each diameter class. This volume was found by multiplying the number of trees present in each diameter class for each year by their respective volumes. In finding this value the true diameter for the year in question had to be considered in one of two ways:

(1) By using the value of volume as determined from the individual curves for each year;

(2) By using the volume of the midpoint of each diameter class and subtracting the amount of growth occurring between the year concerned and the end of the period. The amount of growth was based on the number of trees occurring in the class in the year in question. This second method was used in the compilations of this project.

c. Total increment by diameter classes. This was found by multiplying the growth of the average tree of each diameter class by the number of trees alive in the given year for each diameter class and year.

d. Growth per cent. The increment of each diameter class and year was divided by the corresponding volume of that diameter class and year to give an expression of the growth per cent.

5. Net Increment

a. Net increment in volume. The net increment (volume gain or loss) was calculated by subtracting the mortality for each year and diameter class from the corresponding increment, or vice versa.

b. Net increment in per cent. This was determined by dividing the net increment of each diameter class and year by the corresponding volume.

c. Summarized data on a diameter basis. The addition of the net increments for all years of the period, for each diameter class, gave the total net increment of each class. This, divided by the volume of the corresponding diameter classes at the beginning of the period gave the net increment in per cent for each diameter class.

d. Summarized data on a yearly basis. The sum of the net increment of all diameter classes showed the yearly increment for the plot as a whole. This figure divided by the volume of the corresponding year expressed the net increment in per cent for the entire plot.

Determination of growth of diameter classes not represented by the core analysis data. In cases where no increment borings had been made, in diameter classes in which trees occurred on the plot, or in case of a wide divergence in the amount of growth of some individual class due to abnormality of the measured trees or an insufficient number of samples, it was necessary to construct a curve of average yearly radial growth over diameter. The average yearly radial growth for each diameter class was computed and plotted, a smooth curve drawn through these points, or, if the points were too irregular to serve as the basis for a good curve, a three-class or ~~four~~ five-class moving average was computed, plotted, and a smooth curve drawn.

A three-class moving average was computed in the following manner:

The values of the first three diameter classes (12", 14" and 16") were multiplied by their respective weights (the number of trees in each). These figures were totaled and divided by the sum of the weights. The resultant value was plotted over the midpoint of the class (14"); the same procedure was then followed for the group of the second, third and fourth diameter classes (14", 16" and 18"). This was continued until all the classes had been included. The process of plotting "moving averages" in this way had the effect of smoothing out the original curve so that it was possible to draw a representative curve from which the values of the missing classes could be read. This gave the value for the average year of the period. The relation of each year to this average year had to be found, and this was done by totaling all the growth for any given year and dividing this sum by the total growth of the average year. Multiplying the value obtained from the curve by the percentage relation for each year gave the radial growth of the diameter class in question for each year of the period.

In this project it was necessary to make these additional calculations for two diameter classes--the 48" and the 54". The 48" diameter class was represented by one tree with abnormally high growth, and there were no core analyses for the 54" class, although it was represented in the cruise data by one tree. The largest diameter class for which a core analysis was recorded was the 48" class, and since the data of this class had to be disregarded, it was necessary to project the growth curve from the 46" class to the 54" class. A three-class moving average was used to obtain the general trend for theprojected portion of the curve (Figure 4).

(d) Results.

The results of this project are summarized in Tables 1 to 6.

Table 1 shows the diameter growth and diameter, inside bark, expressed in millimeters for each diameter class in each year of the period.

Table 2 shows volume growth and volume of the average tree of each diameter class.

Table 3 shows the increment in volume and per cent for each diameter class.

Table 4 shows the mortality in number of trees and volume.

Table 5 is a stand and mortality table.

Table 6 shows the net increment, either positive or negative, by volume and by per cent.

Explanation of Tables

From Tables 1 and 2, which express growth in diameter and volume, it is evident that growth is very slow on Plot No. 1. In most cases the yearly diameter growth is less than 1.5 millimeters and for the larger-diameter classes less than 1.0 millimeters. The growth in volume runs from an average of about 0.4 board foot per year in the 12" class to 7 or 8 board feet per year in the largest class.

Table 3 expresses the volume growth for all the trees in each diameter class in volume and per cent. The growth per cent shows a decided downward trend with increasing diameters, although in some cases, especially in the smaller-diameter classes, there is considerable variation, as for example in 1925; during that year the values of growth per cent are seen to have increased between successive diameter classes in a number of cases, although the general trend was downward with increasing diameter.

Table 4 expresses the relationship of mortality and diameter distribution. Most of the loss, in numbers of trees, occurs in the smaller-diameter classes below 40" d.b.h. This is due to the larger number of trees in these classes. The greatest volume loss occurs in classes between 20 and 40 inches d.b.h. This is due to the larger number of trees and also the larger volumes of the trees. Table 5 shows that some of this loss is not due to the greater number of trees and larger volumes, but that these classes seem to be more susceptible to insect attack. If the trees over 46" d.b.h. are not included, the table indicates that the mortality is greatest, in per cent of trees lost, in diameter classes between 20 and 40 inches. The classes above 46" are represented by such a limited number of trees that they cannot be considered, as a loss of one tree may cause a change of 25 to 100 per cent.

Table 6 is a balance sheet of growth and the loss from mortality. It expresses net increment (gain or loss in volume) in volume and per cent. From this table the same relationship of mortality and diameter may be noted that was observed in Table 5; i.e., that most of the loss occurs in the diameter classes between 20 and 40 inches b.h. It also shows the years in which insect infestations were most severe. This period comprises one cycle in insect infestation. It reached a peak in 1927, fell off until 1929 when the low point is reached, and then rose in 1930. In later studies of this plot it was found that in 1931 and 1932 the mortality from insects was again increasing.

Form 6.

Forest

e

Dev.

% Cr.

Exp.

Cond.Man.

Remarks

FORM 3

## SPOTTING RECORD

Project area________________ Unit________________ Camp No.____________

Date______________ Spotter______________ T.______ R.______ Sec.______

| Tree No. | Killed by | D B H | Logs | Volume | | | | Remarks |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Totals, | | | | | | | | |

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TABLE 1

DIAMETER GROWTH AND AVERAGE DIAMETERS, BY YEARS,
FOR EACH 1931 DIAMETER CLASS

| Diameter Breast High o.b. in 1931 inches | 1925 Average Diameter Growth mm. | 1925 Average Diameter Class mm. | 1926 Growth mm. | 1926 Diameter mm. | 1927 Growth mm. | 1927 Diameter mm. | 1928 Growth mm. | 1928 Diameter mm. | 1929 Growth mm. | 1929 Diameter mm. | 1930 Growth mm. | 1930 Diameter mm. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 1.328 | 239.5 | 1.398 | 240.9 | .784 | 241.7 | 1.640 | 243.3 | 1.198 | 244.5 | 1.336 | 245.8 |
| 14 | 1.298 | 280.0 | 1.294 | 281.3 | 1.182 | 282.5 | 1.330 | 283.8 | 1.168 | 285.5 | 1.126 | 286.6 |
| 16 | 1.438 | 322.3 | 1.092 | 323.4 | 1.430 | 324.8 | 1.814 | 326.7 | 1.410 | 328.3 | 1.524 | 329.8 |
| 18 | 1.196 | 366.5 | 1.232 | 367.7 | 1.206 | 368.9 | 1.794 | 370.7 | .986 | 371.7 | 1.342 | 373.0 |
| 20 | .974 | 411.4 | .934 | 412.3 | .928 | 413.3 | 1.214 | 414.5 | .866 | 415.3 | .998 | 416.3 |
| 22 | .896 | 454.7 | .998 | 455.7 | .828 | 456.6 | 1.164 | 457.7 | .802 | 458.5 | .960 | 459.5 |
| 24 | .838 | 509.1 | .828 | 509.8 | .730 | 510.6 | 1.028 | 511.5 | .682 | 512.0 | .864 | 512.7 |
| 26 | .646 | 544.8 | .760 | 545.6 | .738 | 546.3 | .894 | 547.2 | .510 | 547.7 | .708 | 548.4 |
| 28 | .628 | 589.6 | .664 | 590.2 | .682 | 590.9 | .896 | 591.8 | .604 | 592.4 | .742 | 593.2 |
| 30 | .610 | 629.8 | .698 | 630.5 | .696 | 631.2 | .986 | 632.2 | .694 | 632.9 | .808 | 633.7 |
| 32 | .684 | 682.1 | .666 | 682.8 | .644 | 683.4 | .880 | 684.3 | .646 | 685.0 | .644 | 685.6 |
| 34 | .684 | 731.1 | .974 | 732.0 | .696 | 732.7 | .910 | 733.6 | .562 | 734.2 | .712 | 734.9 |
| 36 | .756 | 778.1 | .774 | 778.8 | .720 | 779.6 | 1.068 | 780.6 | .662 | 781.3 | .814 | 782.1 |
| 38 | .560 | 817.5 | .590 | 818.0 | .656 | 818.7 | .854 | 819.6 | .482 | 819.9 | .578 | 820.5 |
| 40 | .426 | 876.4 | .386 | 876.8 | .398 | 877.2 | .526 | 877.7 | .532 | 878.2 | .460 | 878.7 |
| 42 | .514 | 923.9 | .512 | 924.4 | .466 | 924.9 | .574 | 925.4 | .568 | 926.0 | .534 | 926.5 |
| 44 | .600 | 972.2 | .600 | 972.8 | .560 | 973.3 | .740 | 973.9 | .580 | 974.5 | .680 | 975.1 |
| 46 | .660 | 1021.1 | .667 | 1021.8 | .600 | 1022.4 | .814 | 1023.2 | .720 | 1023.9 | .534 | 1024.4 |
| 48 | .430 | 1071.8 | .490 | 1072.3 | .450 | 1072.8 | .600 | 1073.4 | .440 | 1073.8 | .490 | 1074.4 |
| 50 | | | | | | | | | | | | |
| 52 | | | | | | | | | | | | |
| 54 | .390 | 1219.5 | .420 | 1220.0 | .380 | 1220.3 | .510 | 1220.9 | .380 | 1221.2 | .420 | 1221.6 |

TABLE 2

VOLUME GROWTH AND AVERAGE VOLUMES, BY YEARS,
FOR EACH 1931 DIAMETER CLASS

(Volumes by Scribner Decimal C Rule)

| D.B.H. o.b. | 1925 Volume Growth per Tree | 1925 Volume of Tree | 1926 Growth | 1926 Volume | 1927 Growth | 1927 Volume | 1928 Growth | 1928 Volume | 1929 Growth | 1929 Volume | 1930 Growth | 1930 Volume |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | .03 | 2.54 | .06 | 2.60 | .02 | 2.62 | .03 | 2.65 | .05 | 2.70 | .03 | 2.73 |
| 14 | .06 | 4.53 | .07 | 4.60 | .10 | 4.70 | .05 | 4.75 | .10 | 4.85 | .10 | 4.95 |
| 16 | .20 | 8.30 | .10 | 8.40 | .10 | 8.50 | .10 | 8.60 | .20 | 8.80 | .15 | 8.95 |
| 18 | .20 | 13.1 | .10 | 13.2 | .20 | 13.4 | .20 | 13.6 | .20 | 13.8 | .20 | 14.0 |
| 20 | .20 | 20.5 | .20 | 20.7 | .20 | 20.9 | .20 | 21.1 | .20 | 21.3 | .20 | 21.5 |
| 22 | .20 | 29.1 | .20 | 29.3 | .20 | 29.5 | .20 | 29.7 | .10 | 29.8 | .15 | 20.05 |
| 24 | .20 | 43.7 | .10 | 43.8 | .20 | 44.0 | .20 | 44.2 | .20 | 44.4 | .05 | 44.45 |
| 26 | .20 | 59.2 | .30 | 59.5 | .20 | 59.7 | .30 | 60.0 | .20 | 60.2 | .30 | 60.5 |
| 28 | .20 | 75.8 | .30 | 76.1 | .20 | 76.3 | .30 | 76.6 | .20 | 76.8 | .20 | 77.0 |
| 30 | .70 | 93.1 | .30 | 93.4 | .40 | 93.8 | .40 | 94.2 | .30 | 94.5 | .40 | 94.9 |
| 32 | .35 | 115.1 | .20 | 115.3 | .30 | 115.6 | .40 | 116.0 | .30 | 116.3 | .30 | 116.6 |
| 34 | .40 | 136.7 | .70 | 137.4 | .40 | 137.8 | .70 | 138.5 | .30 | 138.8 | .60 | 439.4 |
| 36 | .60 | 161.0 | .40 | 161.4 | .60 | 162.0 | .70 | 162.7 | .50 | 163.2 | .50 | 163.7 |
| 38 | .60 | 182.0 | .60 | 182.6 | .60 | 183.2 | 1.00 | 184.2 | .30 | 184.5 | .60 | 185.1 |
| 40 | .50 | 221.0 | .50 | 221.5 | .50 | 220.0 | .60 | 220.6 | .60 | 221.2 | .70 | 221.9 |
| 42 | .40 | 252.0 | .70 | 252.7 | .60 | 253.3 | .60 | 253.9 | .70 | 254.6 | .50 | 255.1 |
| 44 | .70 | 298.0 | .60 | 298.6 | .40 | 299.0 | .60 | 299.6 | .60 | 300.2 | .60 | 300.8 |
| 46 | .80 | 347.0 | .80 | 347.8 | .60 | 348.4 | .60 | 349.2 | .80 | 350.0 | .60 | 350.6 |
| 48 | .50 | 401.7 | .60 | 402.3 | .70 | 403.0 | .60 | 403.6 | .50 | 404.1 | .80 | 404.9 |
| 50 | | | | | | | | | | | | |
| 52 | | | | | | | | | | | | |
| 54 | .60 | 569.9 | .90 | 570.8 | .60 | 571.4 | 1.20 | 572.6 | .40 | 573.0 | .90 | 573.9 |

TABLE 3
INCREMENT IN VOLUME AND IN PER CENT, BY YEARS,
FOR EACH 1931 DIAMETER CLASS
(Volumes by Scribner Decimal C Rule)

| D.B.H. | 1925 | | 1926 | | 1927 | | 1928 | | 1929 | | 1930 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| o.b. | Volume | % | Volume | % | Volume | % | Volume | % | Volume | % | Volume | % |
| 12 | 15.6 | 1.18 | 31.1 | 2.29 | 10.1 | .76 | 14.7 | 1.11 | 24.3 | 1.86 | 14.4 | 1.10 |
| 14 | 35.0 | 1.75 | 30.2 | 1.51 | 42.2 | 2.11 | 19.9 | 1.05 | 39.4 | 2.06 | 39.1 | 2.02 |
| 16 | 92.6 | 4.23 | 46.0 | 1.39 | 45.4 | 1.32 | 43.8 | 1.27 | 85.0 | 2.57 | 63.4 | 1.89 |
| 18 | 59.6 | 1.56 | 29.4 | .76 | 57.2 | 1.48 | 53.6 | 1.47 | 51.0 | 1.46 | 50.4 | 1.44 |
| 20 | 89.2 | .97 | 86.4 | .94 | 86.4 | .95 | 81.2 | .95 | 78.8 | .94 | 78.6 | .92 |
| 22 | 118.4 | .64 | 117.2 | .64 | 114.6 | .64 | 109.4 | .63 | 53.2 | .51 | 79.6 | .47 |
| 24 | 99.0 | .46 | 49.1 | .23 | 95.2 | .47 | 89.4 | .45 | 87.4 | .45 | 26.7 | .14 |
| 26 | 73.8 | .35 | 109.8 | .55 | 70.8 | .36 | 97.5 | .54 | 61.8 | .36 | 91.5 | .57 |
| 28 | 78.8 | .26 | 85.2 | .29 | 74.8 | .26 | 103.8 | .39 | 66.4 | .26 | 66.2 | .25 |
| 30 | 289.1 | .74 | 122.7 | .32 | 156.4 | .42 | 148.4 | .42 | 108.9 | .31 | 142.4 | .42 |
| 32 | 135.1 | .30 | 76.0 | .17 | 109.5 | .26 | 140.8 | .35 | 104.4 | .26 | 103.8 | .41 |
| 34 | 88.8 | .30 | 152.6 | .52 | 82.8 | .29 | 139.3 | .51 | 88.5 | .33 | 115.2 | .44 |
| 36 | 146.4 | .37 | 96.4 | .25 | 142.2 | .37 | 153.1 | .42 | 113.5 | .31 | 111.5 | .31 |
| 38 | 127.8 | .33 | 123.0 | .33 | 121.2 | .33 | 198.0 | .54 | 57.9 | .16 | 115.2 | .32 |
| 40 | 48.0 | .24 | 47.0 | .24 | 44.5 | .24 | 52.2 | .29 | 51.6 | .28 | 58.1 | .31 |
| 42 | 34.0 | .16 | 59.5 | .28 | 50.4 | .24 | 49.8 | .23 | 57.4 | .28 | 40.5 | .20 |
| 44 | 30.1 | .22 | 25.2 | .20 | 16.8 | .13 | 25.2 | .20 | 24.6 | .20 | 24.6 | .20 |
| 46 | 26.4 | .23 | 26.4 | .23 | 19.2 | .17 | 19.2 | .17 | 25.6 | .23 | 19.2 | .17 |
| 48 | 6.5 | .12 | 7.8 | .15 | 7.7 | .17 | 6.0 | .15 | 5.0 | .12 | 8.0 | .20 |
| 50 | 2.0 | .11 | 2.8 | .15 | 2.1 | .15 | 1.6 | .18 | 1.0 | .11 | 1.6 | .17 |
| 52 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 54 | 6.6 | .11 | 9.9 | .16 | 6.6 | 1.1 | 1.2 | .21 | 4.0 | .07 | 9.0 | .16 |
| 56 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 58 | .6 | .09 | .9 | .13 | -- | -- | -- | -- | -- | -- | -- | -- |
| Totals | 1603.4 | .42 | 1334.6 | .35 | 1356.1 | .37 | 1558.9 | .45 | 1189.7 | .34 | 1259.0 | .37 |

TABLE 4
MORTALITY, BY NUMBER OF TREES AND VOLUME,
FOR EACH 1931 DIAMETER CLASS
(Volumes by Scribner Decimal C Rule)

| D.B.H. o.b. | 1925 No. of Trees in Class | 1925 Volume of Class | 1926 No. of Trees | 1926 Volume | 1927 No. of Trees | 1927 Volume | 1928 No. of Trees | 1928 Volume | 1929 No. of Trees | 1929 Volume | 1930 No. of Trees | 1930 Volume |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 3 | 8.3 | 11 | 30.2 | 16 | 44.0 | 6 | 16.5 | 4 | 11.0 | 1 | 2.8 |
| 14 | 6 | 30.0 | 10 | 50.0 | 24 | 120.0 | 4 | 20.0 | 3 | 15.0 | 1 | 5.0 |
| 16 | 3 | 24.0 | 6 | 48.0 | 16 | 128.0 | 13 | 104.0 | 3 | 24.0 | 2 | 16.0 |
| 18 | 4 | 56.0 | 8 | 112.0 | 18 | 252.0 | 13 | 182.0 | 3 | 42.0 | 2 | 28.0 |
| 20 | 4 | 86.0 | 10 | 215.0 | 26 | 559.0 | 12 | 258.0 | 1 | 21.5 | 2 | 42.0 |
| 22 | 6 | 192.0 | 13 | 416.0 | 26 | 832.0 | 15 | 480.0 | 1 | 32.0 | 8 | 256.0 |
| 24 | 4 | 178.0 | 15 | 667.5 | 29 | 1,290.5 | 10 | 445.0 | 4 | 178.0 | 2 | 89.0 |
| 26 | 3 | 181.5 | 12 | 776.0 | 29 | 1,754.5 | 16 | 968.0 | 4 | 242.0 | 3 | 181.5 |
| 28 | 5 | 387.5 | 15 | 1,162.5 | 28 | 2,170.0 | 14 | 1085.0 | 1 | 77.5 | 1 | 77.5 |
| 30 | 4 | 384.0 | 18 | 1,728.0 | 20 | 1,920.0 | 8 | 768.0 | 7 | 672.0 | 6 | 576.0 |
| 32 | 6 | 700.2 | 15 | 1,750.5 | 13 | 1,517.1 | 4 | 466.8 | 2 | 233.4 | 3 | 350.1 |
| 34 | 4 | 554.0 | 11 | 1,523.5 | 8 | 1,080.0 | 4 | 554.0 | 3 | 415.5 | 2 | 279.0 |
| 36 | 3 | 419.4 | 4 | 655.2 | 4 | 655.2 | 6 | 838.8 | 2 | 327.6 | 2 | 327.6 |
| 38 | 8 | 1488.0 | 3 | 558.0 | 4 | 744.0 | 5 | 930.0 | 1 | 186.0 | 2 | 372.0 |
| 40 | 2 | 428.0 | 5 | 1,070.0 | 2 | 428.0 | 1 | 214.0 | 3 | 642.0 | 3 | 642.0 |
| 42 | 0 | 0 | 1 | 255.0 | 1 | 255.0 | 1 | 255.0 | 1 | 255.0 | 1 | 255.0 |
| 44 | 1 | 302.0 | 0 | 0 | 0 | 0 | 1 | 302.0 | 0 | 0 | 0 | 0 |
| 46 | 0 | 0 | 1 | 351.0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 702.0 |
| 48 | 0 | 0 | 2 | 280.0 | 1 | 410.0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 | 0 | 0 | 1 | 458.0 | 1 | 458.0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 52 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 54 | 0 | 0 | 0 | 0 | 0 | 574.0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 58 | 0 | 0 | 0 | 0 | 1 | 690.0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 66 | 5418.9 | 156 | 12,106.4 | 268 | 15,881.3 | 133 | 7887.1 | 43 | 3314.5 | 43 | 4201.5 |

TABLE 5

NUMBERS OF TREES BY DIAMETER CLASSES, IN 1925,
AND SUBSEQUENT LOSSES

| D.B.H. o.b. | No. of Trees in 1925 | No. of Trees Lost, 1925-1930 | % of Trees Lost |
|---|---|---|---|
| 12 | 521 | 41 | 7.87 |
| 14 | 438 | 48 | 10.96 |
| 16 | 463 | 43 | 9.28 |
| 18 | 298 | 48 | 16.02 |
| 20 | 446 | 55 | 12.31 |
| 22 | 592 | 69 | 11.65 |
| 24 | 495 | 64 | 12.92 |
| 26 | 369 | 67 | 18.15 |
| 28 | 394 | 64 | 16.23 |
| 30 | 413 | 63 | 15.24 |
| 32 | 386 | 43 | 11.14 |
| 34 | 222 | 32 | 14.56 |
| 36 | 244 | 21 | 8.61 |
| 38 | 213 | 23 | 10.70 |
| 40 | 96 | 16 | 16.68 |
| 42 | 85 | 5 | 5.88 |
| 44 | 43 | 2 | 4.67 |
| 46 | 33 | 3 | 9.09 |
| 48 | 13 | 3 | 23.07 |
| 50 | 4 | 2 | 50.00 |
| 52 | -- | -- | -- |
| 54 | 11 | 1 | 9.09 |
| 56 | -- | -- | -- |
| 58 | 1 | 1 | 100.00 |
| Totals: | 5,780 | 714 | 12.35 |

TABLE 6

NET INCREMENT IN VOLUME AND PER CENT, BY YEARS,
FOR EACH 1931 DIAMETER CLASS

(Volumes by Scribner Decimal C Rule)

| D.B.H. o.b. | 1925 Volume Plus | 1925 Volume Minus | 1925 Per Cent Plus | 1925 Per Cent Min. | 1926 Volume Plus | 1926 Volume Minus | 1926 Per Cent Pl. | 1926 Per Cent Minus | 1927 Volume Plus | 1927 Volume Minus | 1927 Per Cent Pl. | 1927 Per Cent Minus | 1928 Volume Plus | 1928 Volume Minus | 1928 Per Cent Pl. | 1928 Per Cent Min. | 1929 Volume Plus | 1929 Volume Minus | 1929 Per Cent Pl. | 1929 Per Cent Min. | 1930 Volume Plus | 1930 Volume Minus | 1930 Per Cent Pl. | 1930 Per Cent Min. | Total Volume Plus | Total Volume Minus | Total Per Cent Plus | Total Per Cent Minus |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 7.3 | | .55 | | .9 | | .07 | | | 33.9 | | 2.54 | | 1.8 | | .14 | 13.3 | | 1.02 | | 11.6 | | .88 | | 5.5 | | 0.41 | |
| 14 | 5.0 | | .25 | | | 19.8 | | .99 | | 77.8 | | 3.95 | | 0.1 | | .01 | 24.4 | | 1.27 | | 34.1 | | 1.76 | | | 44.2 | | 2.21 |
| 16 | 68.6 | | 2.05 | | | 2.0 | | .06 | | 82.6 | | 2.42 | | 60.2 | | 1.75 | 61.0 | | 1.84 | | 47.4 | | 1.41 | | 21.2 | | 0.63 | |
| 18 | 3.6 | | .01 | | | 82.6 | | 2.10 | | 194.8 | | 5.08 | | 128.4 | | 3.53 | 9.0 | | .26 | | 22.4 | | .64 | | | 378.7 | | 9.89 |
| 20 | 3.2 | | .00 | .00 | | 128.6 | | 1.40 | | 472.6 | | 5.22 | | 176.8 | | 2.07 | 57.3 | | .68 | | 36.6 | | .43 | | | 680.9 | | 7.42 |
| 22 | | 73.6 | | .40 | | 298.8 | | 1.63 | | 717.4 | | 3.97 | | 370.6 | | 2.13 | 21.2 | | .13 | | | 176.4 | | 1.04 | | 1615.6 | | 8.74 |
| 24 | | 79.0 | | .38 | | 618.4 | | 1.87 | | 1195.3 | | 6.02 | | 355.6 | | 1.80 | | 90.6 | | .47 | | 62.3 | | .32 | | 2401.2 | | 11.09 |
| 26 | | 107.7 | | .51 | | 666.2 | | 3.31 | | 1683.7 | | 8.57 | | 870.5 | | 4.83 | | 160.2 | | 1.05 | | 90.0 | | .56 | | 3602.8 | | 17.24 |
| 28 | | 308.7 | | 1.02 | | 1087.3 | | 3.70 | | 2095.2 | | 7.02 | | 981.2 | | 3.54 | | 11.1 | | .43 | | 11.3 | | .43 | | 4494.8 | | 14.67 |
| 30 | | 94.9 | | .24 | | 1595.3 | | 4.09 | | 1763.6 | | 4.76 | | 619.6 | | 1.75 | | 563.1 | | 1.62 | | 433.6 | | 1.32 | | 4465.3 | | 14.71 |
| 32 | | 565.1 | | 1.63 | | 1674.5 | | 3.81 | | 1407.6 | | 3.33 | | 326.0 | | .83 | | 129.0 | | .32 | | 246.3 | | .61 | | 4348.5 | | 9.77 |
| 34 | | 465.2 | | 1.55 | | 1370.9 | | 4.52 | | 997.2 | | 3.52 | | 414.7 | | 1.51 | | 327.0 | | 1.22 | | 163.8 | | .62 | | 3738.8 | | 12.42 |
| 36 | | 273.0 | | .69 | | 556.8 | | 1.43 | | 513.0 | | 1.33 | | 685.7 | | 1.87 | | 214.1 | | .59 | | 216.1 | | .60 | | 2460.7 | | 6.26 |
| 38 | | 1360.2 | | 3.49 | | 435.0 | | 1.16 | | 622.8 | | 1.67 | | 732.0 | | 2.00 | | 128.1 | | .36 | | 256.8 | | .72 | | 3534.9 | | 9.06 |
| 40 | | 380.0 | | 1.87 | | 1023.0 | | 5.15 | | 383.5 | | 2.04 | | 161.8 | | .88 | | 590.4 | | 3.22 | | 583.9 | | 3.12 | | 3122.6 | | 15.41 |
| 42 | 34.0 | | .16 | | | 195.5 | | .91 | | 204.6 | | .96 | | 205.2 | | .97 | | 197.6 | | .95 | | 214.5 | | 1.04 | | 983.4 | | 4.56 |
| 44 | | 271.9 | | 2.11 | 25.2 | | .20 | | 16.8 | | .13 | | | 276.8 | | 2.19 | 24.6 | | .20 | | 24.6 | | .20 | | | 457.5 | | 3.55 |
| 46 | 26.4 | | .23 | | | 324.6 | | 2.69 | 19.2 | | .17 | | 19.2 | | .17 | | 25.6 | | .23 | | | 682.8 | | 5.97 | | 917.0 | | 7.86 |
| 48 | 6.5 | | .12 | | | 272.2 | | 5.14 | | 402.3 | | 8.95 | 6.0 | | .15 | | 5.0 | | .12 | | 8.0 | | .20 | | | 649.0 | | 12.30 |
| 50 | 2.0 | | .11 | | | 455.2 | | 24.40 | | 455.9 | | 33.20 | 1.6 | | .18 | | 1.0 | | .11 | | 1.6 | | .17 | | | 904.9 | | 49.60 |
| 52 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 54 | 6.6 | | .11 | | 9.9 | | .16 | | | 574.4 | | 9.01 | 12.0 | | .21 | | 4.0 | | .07 | | 9.0 | | .16 | | | 525.9 | | 8.23 |
| 56 | | | | | | | | | | | | | | | | | | | | | | | | | | 688.5 | | 100.00 |
| 58 | .6 | | .09 | | .9 | | .13 | | | 690.0 | | 100.00 | | | | | | | | | | | | | | | | |
| Totals | | 3815.5 | | 1.00 | | 10761.8 | | 2.85 | | 14525.2 | | 3.97 | | 6328.2 | | 1.82 | | 2134.8 | | .62 | | 2942.5 | | .86 | | 40458.0 | | 11.85 |

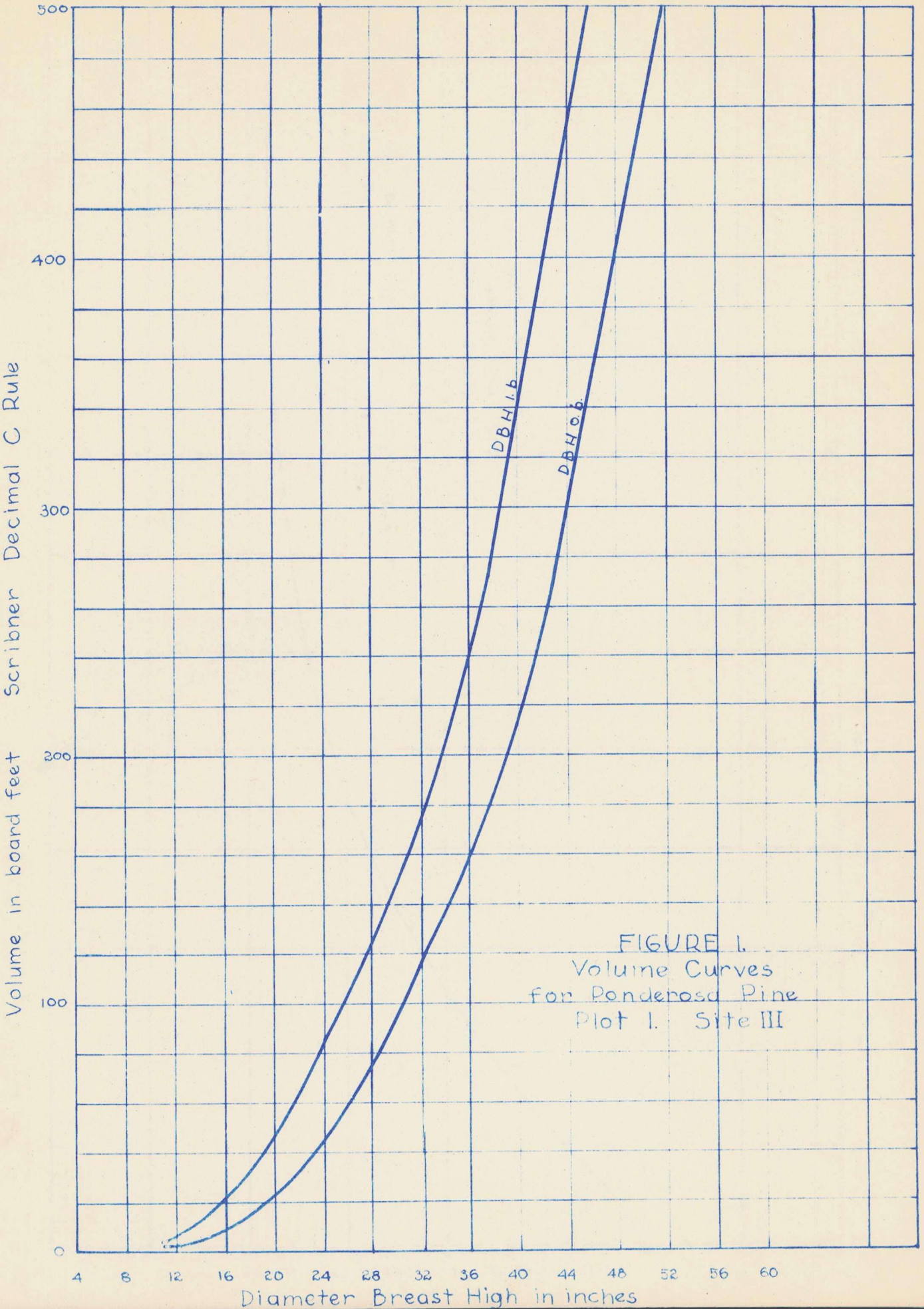


FIGURE 1.
Volume Curves
for Ponderosa Pine
Plot 1. Site III

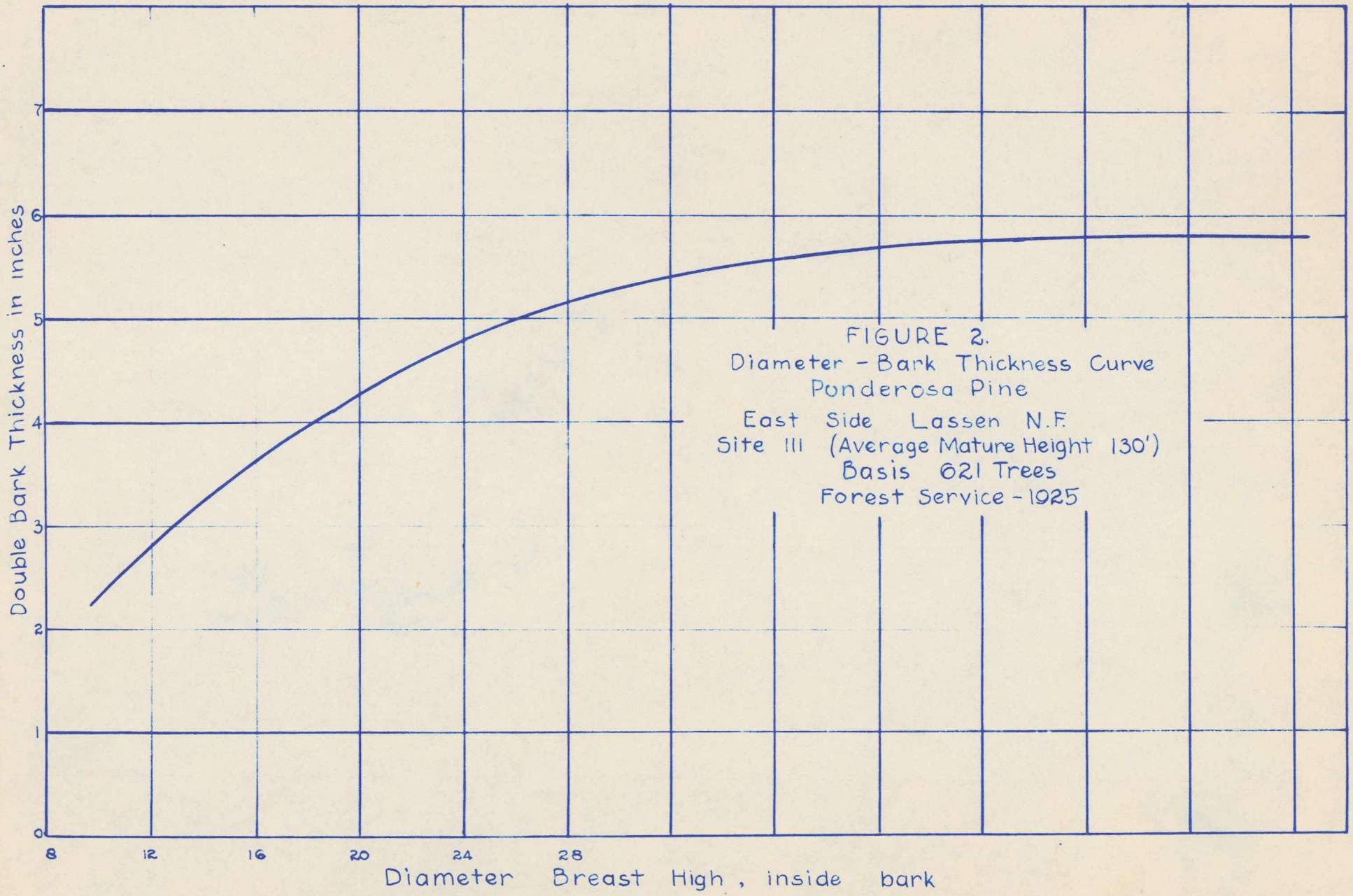


FIGURE 2.
Diameter - Bark Thickness Curve
Ponderosa Pine
East Side Lassen N.F.
Site III (Average Mature Height 130')
Basis 621 Trees
Forest Service - 1925

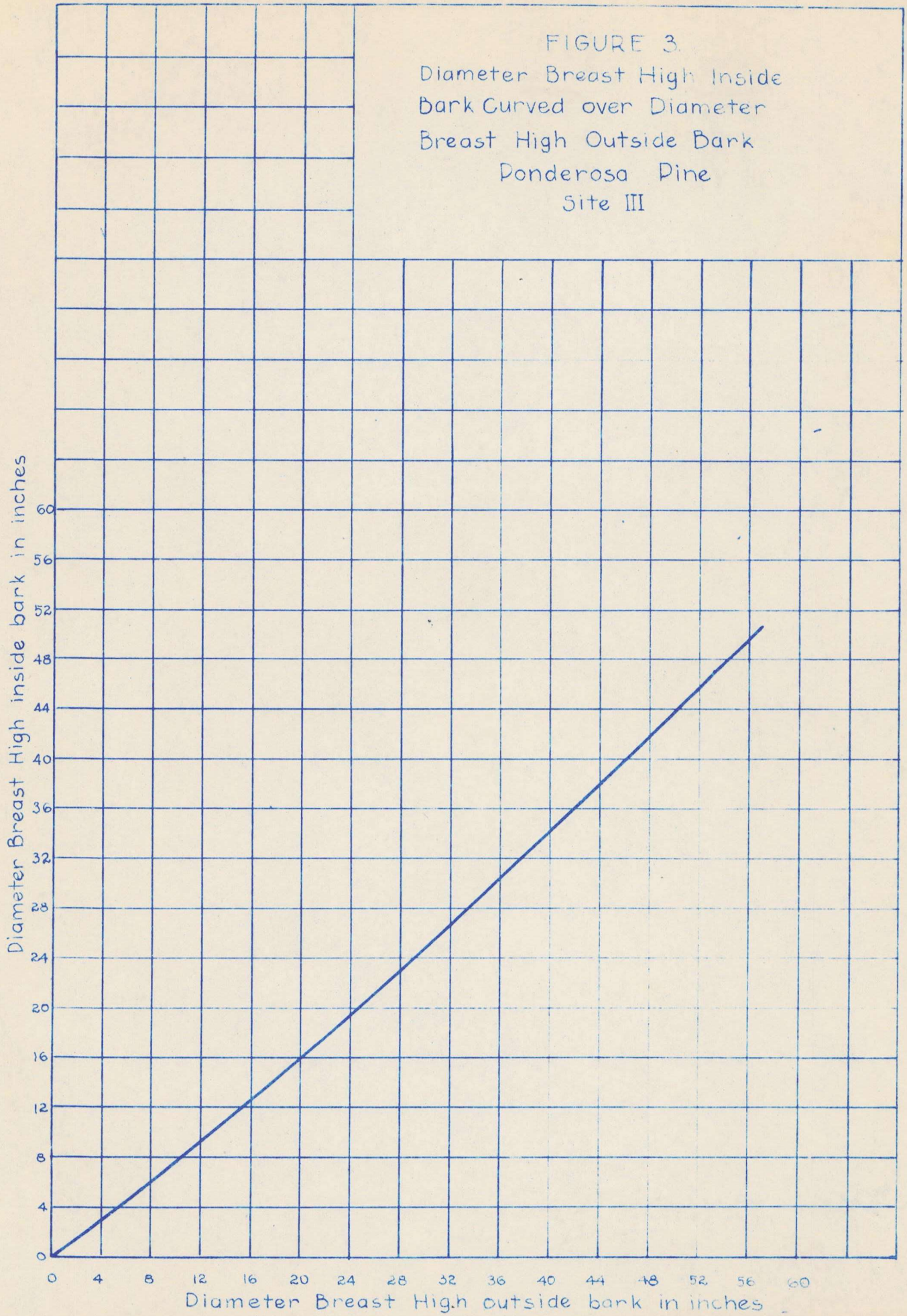


FIGURE 3.
Diameter Breast High Inside Bark Curved over Diameter Breast High Outside Bark
Ponderosa Pine
Site III

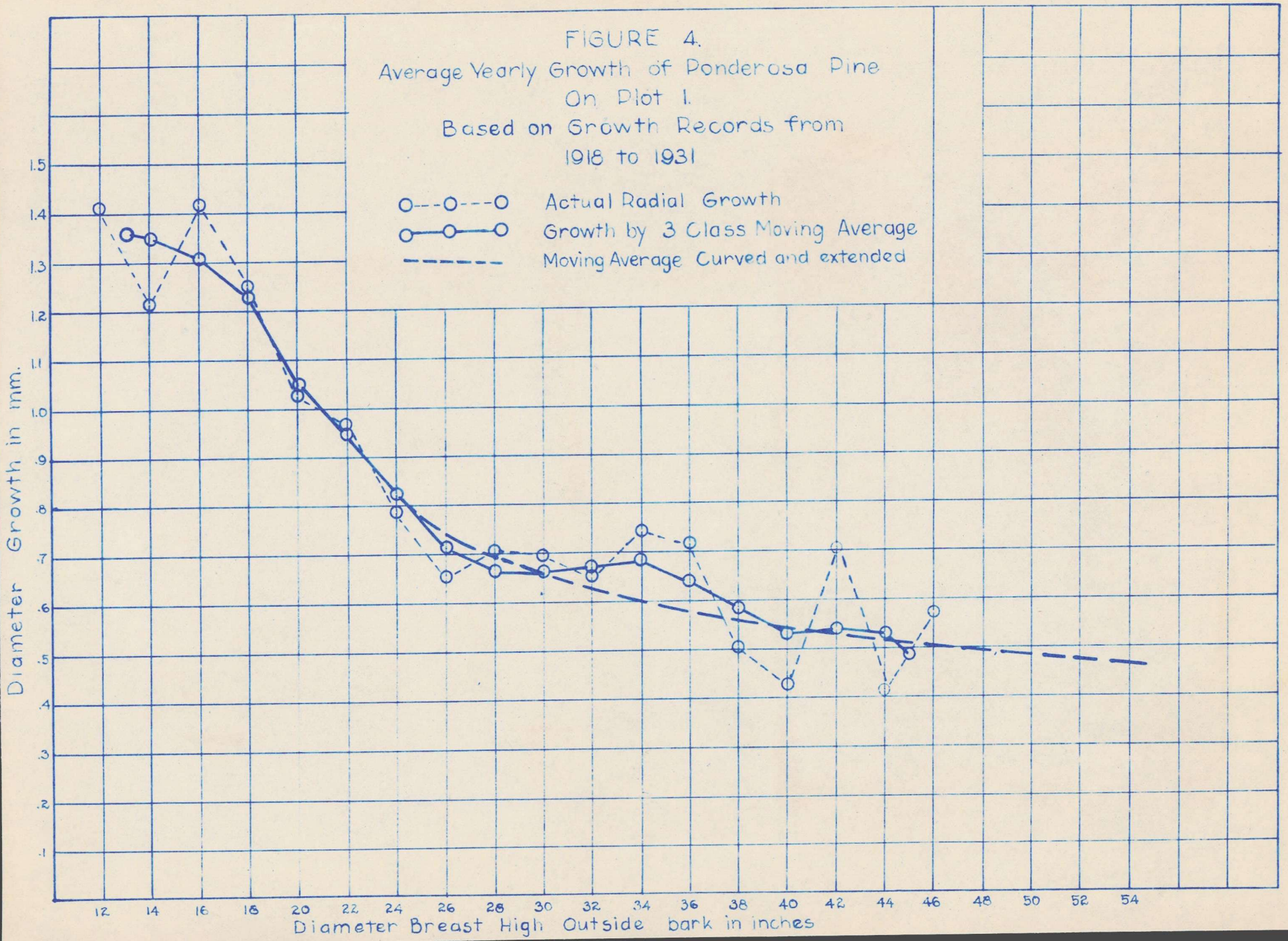
FIGURE 4.
Average Yearly Growth of Ponderosa Pine
On Plot 1.
Based on Growth Records from
1918 to 1931
Actual Radial Growth
Growth by 3 Class Moving Average
Moving Average Curved and extended
Diameter Growth in mm.
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
52
54
Diameter Breast High Outside bark in inches

Photo 7553b. Ponderosa pine forest near Regional Survey Plot 1, showing stand similar to that on study area. By the use of panchromatic film and G filter the foliage of trees recently killed by western pine beetle(1932 summer brood)registers white in the print. A group of 6 insect-killed trees shows in center of photo.

Photo 6532. Airplane view of stand near R.S. 1, taken at elevation of 1500 feet above ground, showing open character of stand. Recent insect-killed trees register white, as in 7553b.

Photo 7437. Group of ponderosa pines on A.S. Plot 1 killed by western pine beetle in 1927, five years before photo was taken.

Photo 7437a. Ground cover and reproduction under group of insect-killed trees shown in 7437.